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Do perceptual consequences of spontaneous otoacoustic emissions reflect a central plasticity effect?

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INTRODUCTION

Spontaneous otoacoustic emissions (SOAEs) are narrow-band signals originating in the inner ear that can be measured in the absence of external acoustic stimulation in at least one third of normal ears (Probst *et al.*, 1991). Although SOAEs are typically regarded as epiphenomena with no functional consequence, there is evidence that their presence affects pitch perception and frequency discrimination. While Köhler and Fritze (1994) reported pitch shifts and elevated frequency difference limens (FDLs) for pure tones near the frequency of SOAEs, Norena *et al.* (2002) found the opposite effect of reduced FDLs in the vicinity of SOAEs. The improved monaural frequency discrimination occurred both ipsilaterally and contralaterally to the emission ear. Consequently, Norena *et al.* (2002) argued for a central origin of the effect, possibly due to prolonged ongoing stimulation of auditory nerve cells tuned to the SOAE frequency, which might lead to an overrepresentation of that frequency at a cortical level and thus facilitate discrimination. In addition to this suggestion of a central plasticity effect, there is strong evidence that SOAEs interact peripherally with external tones of nearby frequencies, such that an external tone that is close enough to an SOAE "entrains" the emission to oscillate at the frequency of the tone (Long and Tubis, 1988; Long 1998). As the external tone is shifted further away from the SOAE, a beating pattern is observed between the two, with consequences for the perceived quality of the tone for levels near threshold (Zurek, 1981; Long 1998).

Hypothesis: Changes in FDLs around SOAEs correlate with nonlinear interactions of the emissions with external tones, such that perceptual consequences of SOAEs may have a peripheral, rather than purely central mechanism.

RESEARCH QUESTIONS

(1) Can Norena *et al*'s (2002) findings be confirmed using an extended test paradigm with subject-specific test freq. instead of fixed?
- *Are FDLs significantly elevated or reduced around SOAEs?*
- *Are FDL variations found in both the ipsilateral and the contralateral ear?*

(2) Is there a link between SOAE entrianment and FDL variation?
- *Are FDLs consistent with the beating and entrainment patterns measured at a similar sensation level (SL) in individual subjects?*

(3) Can a central effect be observed when emulating a SOAE with a continuous low level pure tone, as observed by Norena *et al.* (2002)?
- *Are FDL variations found in the contralateral ear when emulating an SOAE by presenting a continuous pure tone in the ipsilateral ear?*

METHODS

Seven normal hearing subjects (3 females/4 males, ages 24-30 yrs) with a SOAE in the ipsilateral ear and no SOAE in the same frequency range in the contralateral ear.

I. SOAE frequency and level

- SOAE spectra measured in ipsi and contralateral ears [Fig. 1]
- SOAE peak amplitude L_0 and frequency F_0 determined by power spectrum estimation based on the Welch method (Talmadge *et al.*, 1993).

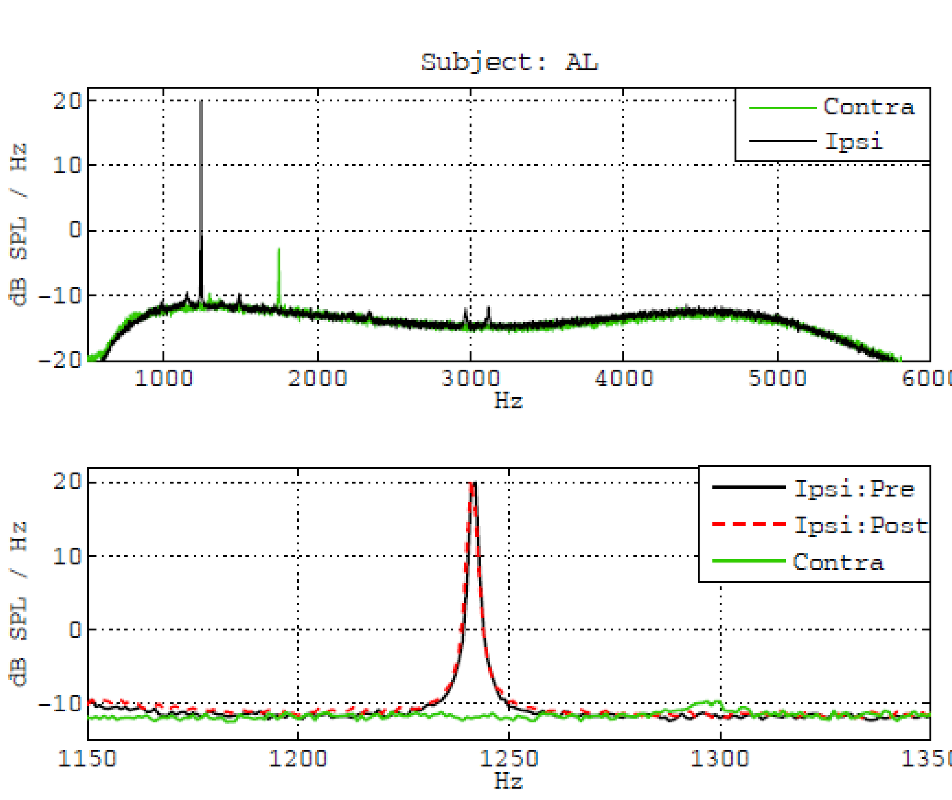

Figure 1: *Top:* OAE spectra for subject S1. *Bottom:* Close-up of SOAE of interest, measured at the beginning of the session (Ipsi: Pre) and 30 minutes later (Ipsi:Post), and in the contra ear.

II. Entrainment patterns

- 60-s ascending sweep presented around F_0 (±50 Hz)
- Sweep levels between -10 and +15 dB re L_0, in steps of 5 dB
- Recordings bandpass filtered around F_0, fullwave rectified, then lowpass filtered (20 Hz) to extract the resulting envelope [Fig. 2 (A)]
- Ipsilateral SOAE measurement repeated to check for frequency and level drifts due to probe insertion (Whitehead, 1991)

III. Hearing thresholds

- Adaptive single-interval up-down method (Lecluyse and Meddis, 2009)
- Hearing threshold (HT) = average of two repetitions for each test frequency

IV. Entrainment and beating regions

- HT at F_0 determined and measured entrainment pattern for ca. 10 dB SL identified
- Spectral widths of entrainment regions below and above F_0, ΔF_{E-} and ΔF_{E+}, determined as transition between entrainment and intermittent beating [Fig. 2 B]
- Remaining test frequencies calculated as $F_x = F_0 - p_x\Delta F_{E-}$ for x<0 and $F_x = F_0 + p_x\Delta F_{E+}$ for x>0, with p_x = [0.75, 3.5, 7, 14] for $|x|$ = [1, 2, 3, 4]
- HT measured at all test frequencies
- Entrainment at each F_x also determined spectrally by measuring SOAE level in the presence of a 10 dB SL pure tone at F_x

V. Frequency difference limens

- 2-interval, 2-AFC paradigm with 1-up 2-down procedure
- Two 500-ms tones logarithmically equidistant from F_x
- 250-ms silent gaps between tones, 20-ms gating
- Starting value 4% of F_x, factor stepsizes [4, 2, √2], 6 reversals with final stepsize
- Level: 10 and 30 dB SL, derived from linear interpolation of measured HTs

VI. Emulating a SOAE with a pure tone

- Ipsi and contralateral region void of SOAEs and closest to geometrical frequency average of F_0s across subjects chosen as test center frequency F_0
- Average width of entrainment patterns across subjects as % of F_0 used as ΔF_{E-} & ΔF_{E+}
- Test frequencies F_x calculated as before (see **IV.**)
- HTs measured for test frequencies in ipsi and contra ear
- Continuous ipsi pure tone (0, 30 dB SL) while measuring FDL in ipsi (0 dB SL) or contra ear (10, 30 dB SL)

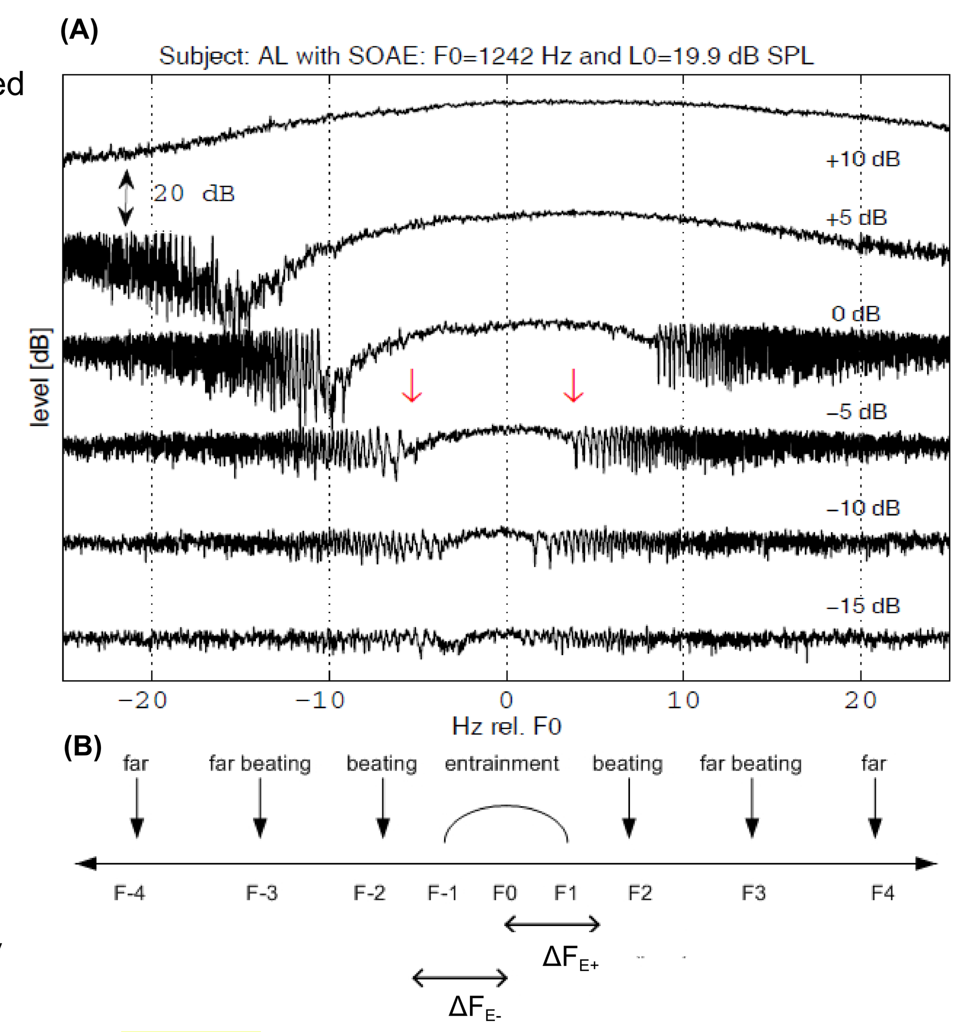

Figure 2 *(A):* SOAE entrainment patterns measured with linear sweeps in steps of 5 dB rel. to SOAE level. Patterns are displaced by 20 dB for visual purposes. Red arrows indicate the estimated boundaries of the entrainment region for the pattern measured closest to 10 dB SL. *(B):* Entrainment- and beating regions with corresponding test frequencies and entrainment pattern width.

RESULTS AND INTERPRETATION

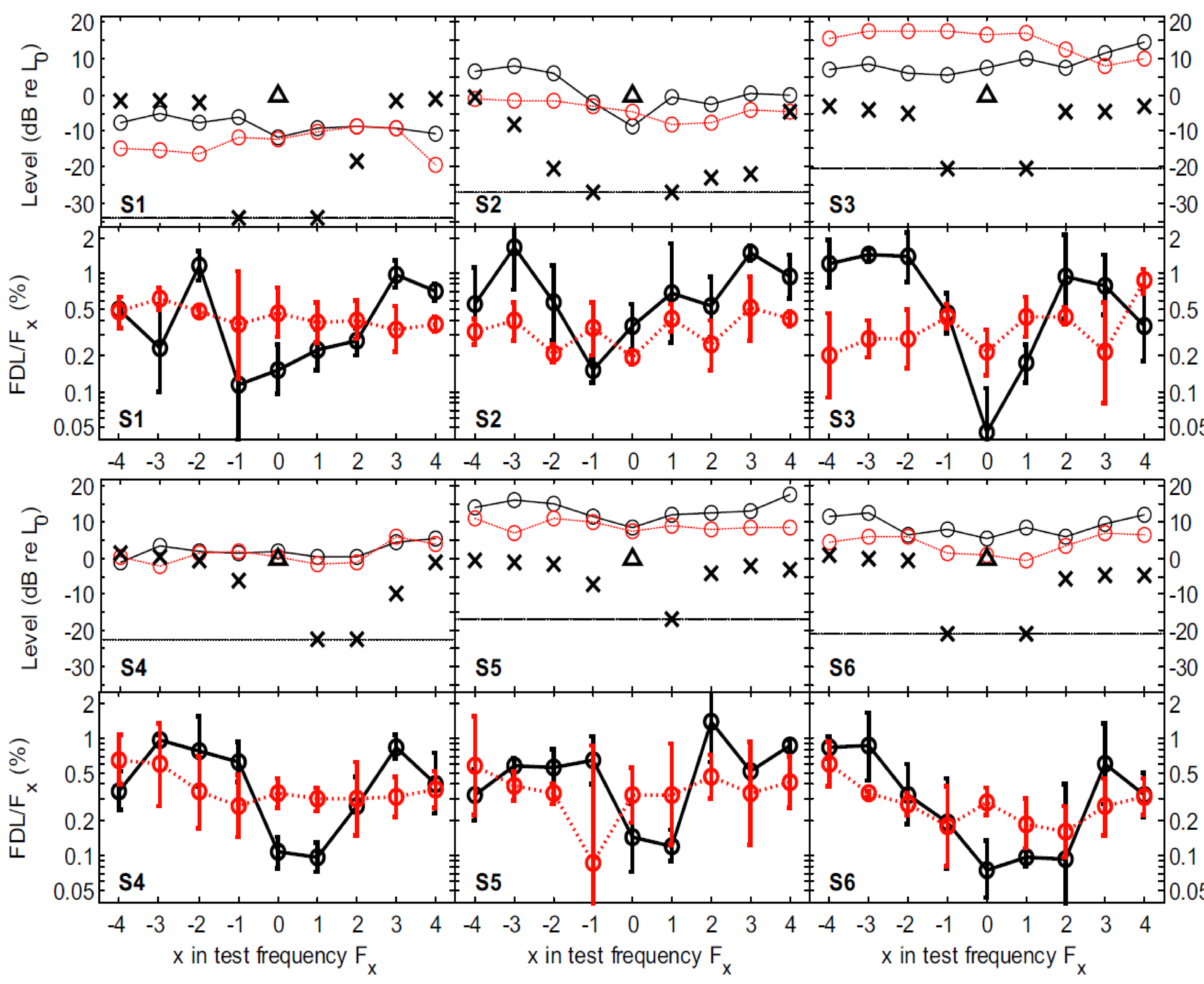

Figure 3: Measurements around SOAE at F_0. Individual objective and subjective results as a function of test frequency F_x. *Top panels:* For each subject, the pure-tone hearing thresholds measured ipsilaterally (solid black curve) and contralaterally (dashed red curve) to the emission ear are shown relative to the level of the SOAE of interest L_0, indicated by the triangle. Crosses indicate the SOAE level in the presence of an external pure tone at 10 dB SL at F_x. The noise floor (dashed black line) corresponds to about -14 dB SPL. *Bottom panels:* The FDLs measured ipsilaterally (solid black curve) and contralaterally (dashed red curve) to the SOAE in the same subjects are plotted as a proportion of F_x. The geometric means and standard deviations over 3 measurement blocks are shown.

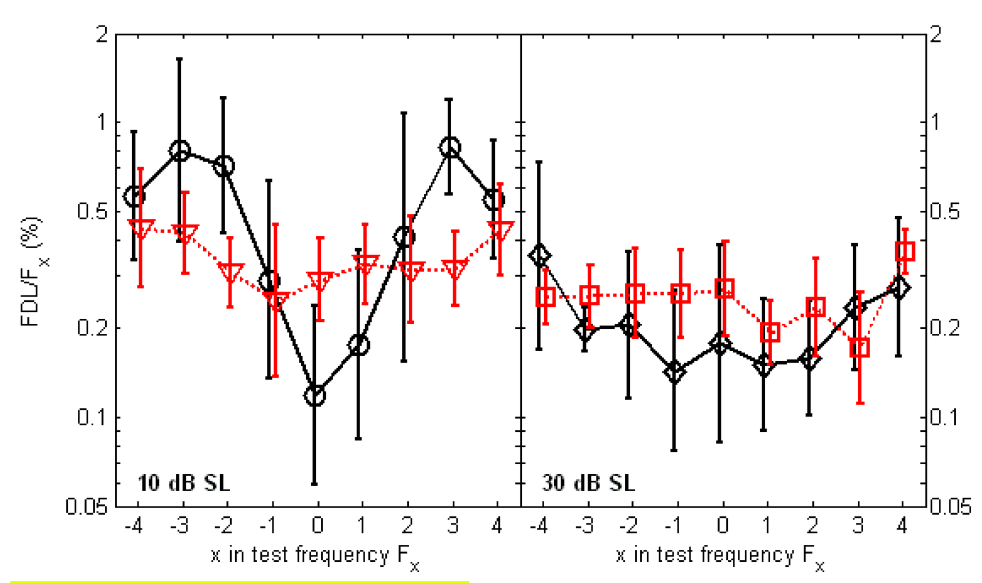

Figure 4: FDLs around SOAE. *Left:* Geometric mean and standard deviations of FDL for six subjects in ipsi ear (solid black, circles) and contralateral ear (dashed red, triangle) measured at 10 dB SL. *Right:* FDL for 5 subjects in ipsi ear (solid black, diamonds) and contra ear (dashed red, squares) measured at 30 dB SL.

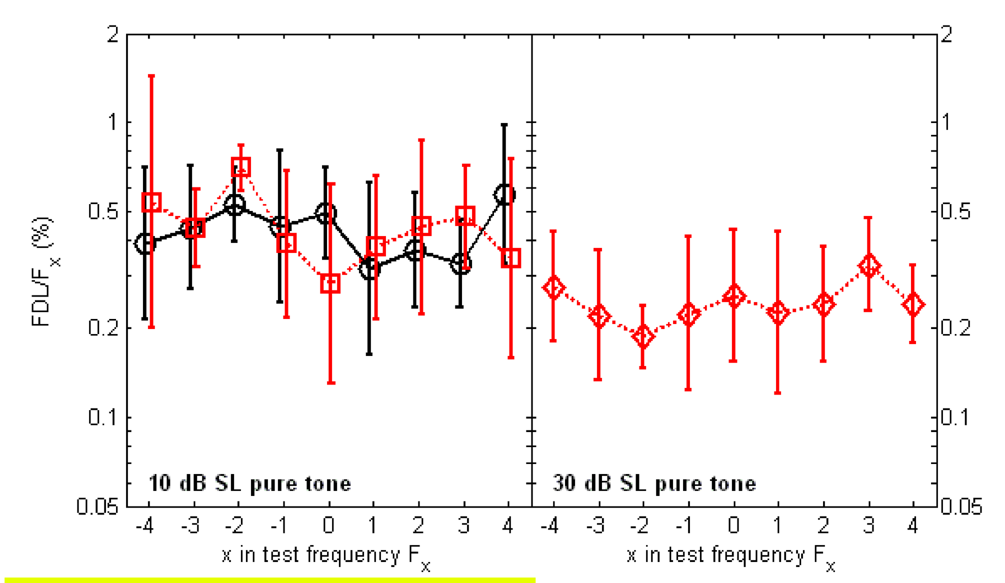

Figure 5: FDLs around emulated SOAE. *Left*: Geometric mean and standard deviations for 5 subejcts in ipsi (solid black, circles) and 6 subjects in contra ear (dashed red, triangle) measured at 10 dB SL FDL in the presence of 0 dB SL pure tone in ipsilateral ear. *Right:* FDL for 5 subjects in contra ear (dashed red, diamonds) measured at 30 dB SL FDL in the presence of ipsilateral 30 dB SL pure tone.

I. Entrainment of SOAE

- Ipsilateral entrainment and beating patterns observed in all subjects
- Drop in SOAE level in the presence of 10 dB SL tone confirms entrainment around SOAE frequency F_0 [Fig.3 Top Panels, crosses]

II. FDLs around SOAE

- FDL trend is reflected in average group results [Fig. 4] despite individual differences in entrainment widths
- Ipsilateral FDL (for 10 dB SL) improves when the SOAE is entrained and becomes worse when there is beating [Fig. 3, bottom panels, solid black curves] [Fig. 4, left, solid black, circles].
- Ipsilateral FDL variations largely consistent with SOAE level changes [Fig. 3, top panels, crosses] in individual subjects
- Ipsilateral FDL trend is less pronounced for 30 dB SL FDL but is still significant [Fig. 4, Right, solid black, diamonds]

➡ Suggests a contribution of peripheral mechanisms to variations in frequency discrimination around SOAEs

- No clear dependence of contralateral FDLs on test frequencies F_x for FDL presentation levels 10 and 30 dB SL [Fig. 4, dashed red curves]

➡ Cannot confirm the role of a central mechanism, as suggested by Norena *et al.* (2002)

III. Emulated SOAE

- No consistent dependence of FDL on F_x with continuous ipsilateral 0 and 30 dB SL pure tone [Fig. 5]

➡ No clear evidence of a central effect!

These findings argue for a peripheral origin, at least in part, for the observed changes in pitch perception around SOAE frequencies, due to the nonlinear interaction of SOAEs with external tones in the cochlea.

REFERENCES

Köhler, W., Fritze, W. (1994). *Acta Otolaryngol.* 114, 110-112.
Lecluyse, W., Meddis, R. (2009). *J. Acoust. Soc. Am.* 126, 2570-2579.
Long, G. (1998). *Hear. Res.* 119, 49-60.
Long, G. R., Tubis, A. (1988). *Hear. Res.* 36, 125-138.
Norena, A., Micheyl, C., Durrant, J. D., Chéry-Croze, S., Collet, L. (2002). *Hear. Res.* 171, 66-71.
Probst, R., Lonsbury-Martin, B. L., Martin, G. K. (1991). *J. Acoust. Soc. Am.* 89, 2027-2067.
Schloth, E. (1983). *Acustica* 53, 250-256.
Talmadge, C. L., Long, G. R., Murphy, W. J., Tubis, A. (1993). *Hear. Res.* 71, 170-182.
Whitehead, M. L. (1991). *Hear. Res.* 53, 269-280.
Zurek, P. M. (1981). *J. Acoust. Soc. Am.* 69, 514-523.